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HISTORY OF THE ARPA SYNTHETIC ENVIRONMENTS FOR REQUIREMENTS AND CONCEPT EVALUATION AND SYNTHESIS (SERCES) PROGRAM

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This report documents the key activities and accomplishments of the ARPA Synthetic Environments for Requirements and Concept Evaluation and Synthesis (SERCES) program. The program objective was to demonstrate how distributed simulation could assist in the Defense acquisition process. SERCES sought to merge together several dispersed development simulation activities, to conduct a case study relating to a system within the acquisition process, and to offer tools which could aid other acquisition programs. DARPA, the Unmanned Aerial Vehicle Joint Program Office (UAV JPO), and the Naval Command, Control, and Ocean Surveillance Center's Navy Research, Development, Test and Evaluation Division (NRaD) agreed to conduct a set of exercises which would support the Maritime Unmanned Aerial Vehicle (MUAV). This report reviews the interconnections which were made between the UAV JPO's Joint Development Facility in McLean, Virginia, and the NRaD's Research, Evaluation and System Analysis (RESA) facility in San Diego, California. The results of the initial exercise and of simulations conducted in preparation to the second exercise are described. Also discussed is a process modeling tool that was developed and used for exercise preparation.

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PREFACE

This document was prepared by the Institute for Defense Analyses (IDA) under the Task Order, Application of Distributed Manned Simulation to the DoD Acquisition Process, and relates to an objective of the task, to "examine case studies in applying distributed manned simulation to the acquisition process." The work was sponsored by the Advanced Research Projects Agency (ARPA).

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EXECUTIVE SUMMARY

In 1991 the Advanced Systems Technology Office (ASTO) of the Defense Advanced Research Projects Agency (DARPA) initiated the Synthetic Environments for Requirements and Concept Evaluation and Synthesis (SERCES) program. The objective of the program was to demonstrate how distributed simulation could assist in the defense acquisition process. SERCES sought to merge together several dispersed development simulation activities, to conduct a case study which would contribute in some aspect to a system which was within the acquisition process, and to offer some long lasting tools which could aid other acquisition programs. Each of these objectives was accomplished in varying detail.

A memorandum of agreement was signed between DARPA, the Unmanned Aerial Vehicle Joint Program Office (UAV JPO), and the Naval Command, Control, and Ocean Surveillance Center's Navy Research, Development, Test and Evaluation Division (NRaD) to conduct a set of exercises which would support the Maritime Unmanned Aerial Vehicle (MUAV)[1] which had been offered as part of a case study. The goal of the case study was to obtain significant data to help in the system specification of vehicle performance, mission assignments, and operational procedures. The simulation activities which were to be interconnected were the UAV JPO's Joint Integration Interface (JII) Joint Development Facility (JDF) in McLean, Virginia, and the NRaD's Research, Evaluation, and System Analysis (RESA) facility in San Diego, California. During the conduct of the effort several outside factors caused the scope of the effort to be reduced, and although the overall objective was not reached, significant accomplishments were made. These included the following:

- An initial exercise was conducted in which the scenarios were defined and evaluated, mission effectiveness parameters established, basing concepts reviewed, and operational sensors payloads evaluated. This exercise included field personnel who operated the subsystems and "flew" the modeled MUAV.

[1] Later renamed the Vertical Take-off and Landing - Unmanned Aerial Vehicle (VTOL-UAV).

- Simulation connections were made between the two sites, i.e., JDF and RESA. Engineering and scenario data was exchanged and *pseudo* VTOL-UAV missions were flown to check out various subsystems and operations.
- An expanded process modeling system tool was developed which facilitated the definition and execution of the many diverse activities needed to conduct a distributed simulation exercise.

The exercise and distributed simulations helped the UAV JPO better understand the possible uses of the VTOL-UAV in Reconnaissance, Surveillance, and Target Acquisition, Over-the-Horizon Targeting, and Anti-Ship Missile Defense missions. It gave insights into the relationships among speed, range, endurance, payload, and launch and recovery aspects of the system performance factors. It also helped in understanding the options regarding who tasks the vehicle and other concepts of operations.

The next potential step is the incorporation of the key SERCES developments within the WAR BREAKER program. The process model is planned to be used within some of its distributed simulation developments. Some of the UAV mission and performance specifications may be studied in greater detail when that system is included within the WAR BREAKER scenarios involving attacking critical mobile targets.

1. INTRODUCTION

This paper provides an overview of the Synthetic Environments for Requirements and Concept Evaluation and Synthesis (SERCES) program, sponsored by the Advanced Research Projects Agency (ARPA)/Advanced Systems Technology Office (ASTO).[1] The objective of the SERCES program was to demonstrate how distributed simulation could assist the DoD acquisition process, with the results from the SERCES program evolving into a model which would aid in future system development and acquisition processes.

1.1 PROGRAM GOALS

SERCES sought to merge together several dispersed development simulation activities to improve the requirements portion of the development of new system acquisition programs. The Maritime Unmanned Aerial Vehicle (MUAV) was offered as a test case for SERCES by the Navy Vertical Take-off and Landing - Unmanned Aerial Vehicle (VTOL-UAV) Program Office (PMA-263). Agreements to accomplish the SERCES objective were made between ARPA and the Unmanned Aerial Vehicle Joint Program Office (UAV JPO). In particular, two simulation activities were to be interconnected:

- The UAV JPO's Joint Intergration Interface (JII) Joint Development Facility (JDF) at Tyson's Corner, Virginia, and
- The Research, Evaluation and System Analysis (RESA) facility of the Navy Research, Development, Test and Evaluation Division (NRaD) at the Naval Command, Control, and Ocean Surveillance Center, San Diego, California.

The initial challenge by the UAV JPO to the SERCES program was to obtain significant data to help justify such system specifications [Taylor 1992] as:

- Performance aspects: Speed, range, endurance, payload, launch and recovery.

[1] At the initiation of the SERCES program, ARPA was still referred to as the Defense Advanced Research Projects Agency (DARPA).

- Mission assignments: Reconnaissance, Surveillance, and Target Acquisition (RSTA), Over-the-Horizon Targeting (OTH-T), and/or Anti-Ship Missile Defense (ASMD).
- Operational procedures: Who tasks and controls the MUAV, i.e., the CONOPS (Concept of Operations).
- Ship interface: Utilization of existing equipment and manpower.

SERCES was also to assist in gaining insights regarding the integration of system-level engineering evaluations, asking such questions as "Does the system work?" For example, by studying the employment of force-level evaluation concepts, what characteristics are most needed in the system?

During the course of the SERCES demonstration effort, its goals were significantly changed. The name "MUAV" was changed to Vertical Take-off and Landing-Unmanned Aerial Vehicle (VTOL-UAV). Also the VTOL program was directed by the Assistant Secretary of the Navy for Research, Development and Acquisition (ASNRDA) to complete a technology demonstration project before a formal DoD acquisition milestone decision would be made. This technology demonstration project was to concentrate on developing and demonstrating the capabilities of critical VTOL-UAV subsystems. These changes, along with a revision of priorities of efforts within ARPA/ASTO, caused the scope of the SERCES program to be reduced. Even with these changes, significant accomplishments were attained; this history will discuss those accomplishments.

1.2 PROGRAM PLAN

The initial program plan for the demonstration[2] was established wherein four experiment sets were to be conducted. Each succeeding experiment set would have increasing complexity, and the fourth set would simulate most of the major activities and/or subsystems needed to conduct an MUAV mission. The experiments were to investigate and help finalize operational utility via a level-of-force structure analysis, platform-level design trade-offs, and hardware-in-the-loop system testing. Simulation technology was developed to support these experiments and included new simulation linkages (facility-to-facility and facility-to-ship), enhanced system-level UAV simulation, and prototype protocols for distributed processing in aggregate-level simulation. The four exercise sets as initially outlined were as follows:

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[2] See the SERCES Project Plan [NRaD 1992b] and [Tiernan 1992]).

1. **MUAVEX-01**: By utilizing the NRaD's RESA simulation facility, the methodology for assessing the MUAV was to be developed. Scenarios were to be defined, mission effectiveness to be established, basing concepts reviewed, basic system parameters defined, and optional sensor payloads evaluated.
2. **MUAVEX-02**: More detailed evaluations of the system concept were to be evaluated. A distributed simulation network was to be established among the RESA and the JDF. With these interconnected facilities, enhanced evaluations were to be performed on such subsystems and concepts as flight simulation, Mission Planning and Control System (MPCS), basing concept, performance parameters, tasking concepts, imagery dissemination, and human factors.
3. **MUAVEX-03**: The activities of the second exercise were to be expanded by extending the network to include interconnections directly to an MPCS and other subsystems which were to be integrated within the combat information center (CIC) of a DDG-51 class ship while it was docked. The evaluations were to include a more detailed analysis of interface problems with a potential ground combat user, scenario dependencies, force structures, and related operations analyses and parameter trade-offs.
4. **MUAVEX-04**: This effort was to expand MUAVEX-03 by having the ship at sea and include additionally available MUAV hardware which would replace some of the JDF simulation equipment.

These experiments were to occur over a two-year period. They required close cooperation among all the participants, many of whom would be added during the course of the program.

Significant changes were made in the program in early 1993. At that time the Navy changed the VTOL-UAV program to a technology demonstration project, and ARPA needed to reassess its priorities and funding allocations. The result was a reduction of the SERCES scope. Since MUAVEX-01 was completed and plans for MUAVEX-02 were underway at the time of the change, ARPA and the UAV JPO initially agreed not to conduct the last two experiments but instead to refine the process model that was developed during the planning for MUAVEX-02, change the name of that exercise to SERCESEX-02, and conduct SERCESEX-02 by September 1993. However, in the March-May 1993 time frame, both organizations finally decided not to conduct the SERCESEX-02. Efforts were continued, however, with the development of a simulation-related program process model.

There was the possibility that some of the planned activities within SERCESEX-02 could be incorporated within the Phase 2 activities of another ARPA/ASTO program, WAR BREAKER.

The SERCES program was formally completed in September 1993. At that time the process model was demonstrated and offered significant aid in the detailed planning of a distributed manned simulation system. SERCES had already conducted MUAVEX-01 within RESA; that exercise helped refine possible VTOL-UAV operations. Some detailed engineering activities were completed in preparation of SERSESEX-02; these will be of benefit during any inclusion of the SERCES-type efforts within the WAR BREAKER Phase 2 or later activities.

1.3 OUTLINE OF PAPER

- The summary of numerous related activities and initial efforts of the SERCES program is given in Section 2.
- The activities and accomplishment of MUAVEX-01 are described within Section 3 of this paper.
- A summary of the planning for SERCESEX-02 is given within Section 4.
- Section 5 contains a more detailed description of the program process model that was developed during the planning for SERCESEX-02.
- A summary of the SERCES efforts is given in Section 6.
- A list of references cited and a list of acronyms used in this document are provided at the end.

2. INITIAL STAGES OF THE PROGRAM

This section addresses the initial stages of the program definition, the selection of an acquisition program, and the various facilities that would be used.

2.1 DISTRIBUTED ASSESSMENT AND SYNTHESIS LABORATORY (DASL)

In late 1991, DARPA conceived the concept for a Distributed Assessment and Synthesis Laboratory (DASL). The DASL was to perform the following:

- Synthesize multiple system simulations to interactively develop, evaluate, and validate operational needs, requirements, concepts, and designs in an extensive combined arms distributed simulation environment.
- Develop a generic system of tools and methods whose use substantially improved the requirements definition, system conception, and technology acquisition process.

The goal was, through the use of DASL, to develop an expanded simulation tool which would be available to help aid program offices to more effectively develop new weapon systems. The DASL concept is shown in Figure 1. The concept seeks to enhance the communication and understanding among all of the various functional communities involved in the acquisition process.

DARPA recognized that a demonstration alone may not be enough to evaluate this idea so a complementary task was given to the Institute for Defense Analyses (IDA) to evaluate the concept of applying distributed manned simulation to the acquisition process. IDA analysis reported [Hammond 1993] that such an application was shown to have the capability to enhance understanding and improve the effectiveness of the acquisition process.

2.2 RELATED PROGRAMS WHICH PRECEDED SERCES

In the mid-1980s, the DARPA Simulator Network (SIMNET) demonstrated the ability to use networks of manned simulators as effective tactical training systems. SIM-

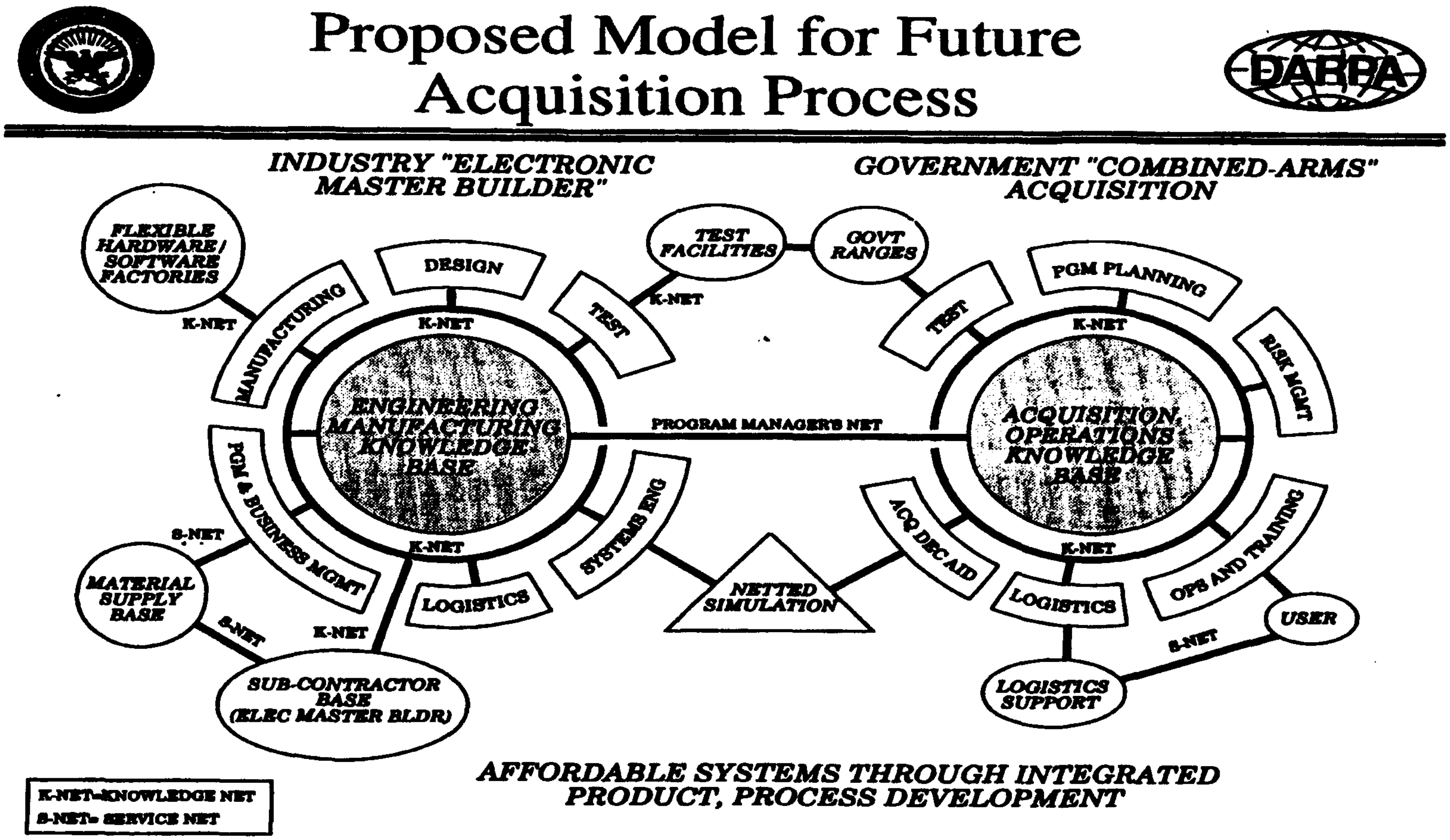

Figure 1. Evolving Model for Future Acquisition
(Source: Neyland 1991)

NET provided the technology start for military applications of distributed warfighting by advancing the technologies of local area networks, long haul networks, computer image graphics, selective fidelity, and mass production of low cost simulators and simulations.

In an extension of those technologies, DARPA and the Navy sponsored a proof-of-principle effort to demonstrate the technology feasibility of advancing SIMNET technologies to create an extended training and evaluation capability. The demonstration, called battlefield in-port training (BFIT), joined together, in a distributed simulation manner, representations of tanks in Ft. Knox, Kentucky, helicopters in Ft. Rucker, Alabama, the USS *Wasp* battle stations while it was pierside at the Norfolk Naval Station, Norfolk, Virginia, and several Navy school trainers.

In the late 1980s SIMNET was transitioned into the Distributed Interactive Simulation (DIS) program. DIS seeks to broaden the scope of SIMNET and include a larger number of entities within the simulation as well as a larger number of simulation and simulator sites. The DIS effort, although funded mostly by ARPA and the Defense Modeling and Simulation Office (DMSO), involves a large number of government and civilian organizations. Collectively they are defining the implementation aspects of the concept. A major outcome of those efforts has been the development of the IEEE Standard 1278 which describes the communication protocol used in sending information among the various distributed simulations.

2.3 RELATIONSHIP WITH UAV JPO AND THE VTOL-UAV PROGRAM OFFICE

ARPA began looking for another demonstration application in 1991 to build on the SIMNET and BFIT experience. Based on a limited survey of acquisition offices for new programs, agreements were eventually made with the UAV JPO. The VTOL-UAV program office expressed interest in using the SERCES concept to help it address major performance, mission, operations, and human factors issues associated with the VTOL-UAV program. Substantial data was needed to support its requirements documents and the development of detailed specifications prior to awarding a preliminary design contract.

2.4 FACILITIES INVOLVED IN SERCES

Two major facilities were considered for inclusion within the SERCES program, the UAV JPO's JDF and NRaD's RESA facility. The major attributes of each are discussed in the following sections.

2.4.1 The Joint Development Facility

It was envisioned that SERCES would use several existing UAV JPO simulations and, in particular, the capabilities within the JDF, which were created to help the UAV JPO in achieving UAV interoperability and commonality.[3] Functions performed within the JDF include the following:

- Requirements development for the family of UAVs
- UAV system modeling and simulation
- Joint integration interface verification
- Integrated program support environments
- Process modeling support conducted by the VTOL-UAV program office

To accomplish these objectives, the JDF developed the necessary detailed interface specifications which related the many different electronic subsystems needed to support UAV operations. Among the many capabilities of the JDF was a communication network which connected potential key electronics subsystems—inertial systems, Forward Looking Infrared (FLIR), radar, command and control (C^2), communications, and mission planning and control. Having this network capability established, it would be relatively easy to connect either model representations or the actual hardware of those subsystems to the network to verify their performance. For the SERCES application, those simulations and hardware would be connected into a distributed simulation network and thus be part of the process to evaluate the effectiveness of alternative designs. The JDF architecture is shown in Figure 2.

2.4.2 The Research, Evaluation and System Analysis Facility

To incorporate ships, aircraft, and other maritime objects and environments into the SERCES demonstration, the RESA simulation facility was included in the SERCES network. RESA, which had its beginning as a Warfare Environment Simulator in 1978-1980, is currently a large-scale, interactive computer simulation facility with a flexible user friendly design. RESA has a broad set of capabilities that include the following:

- Simulation of nearly all Naval warfare environments
- Simulated decision-making and actions at the theater, battle force and/or group, and platform levels

[3] The JDF supports all of the various UAVs under the JPO's development responsibility.

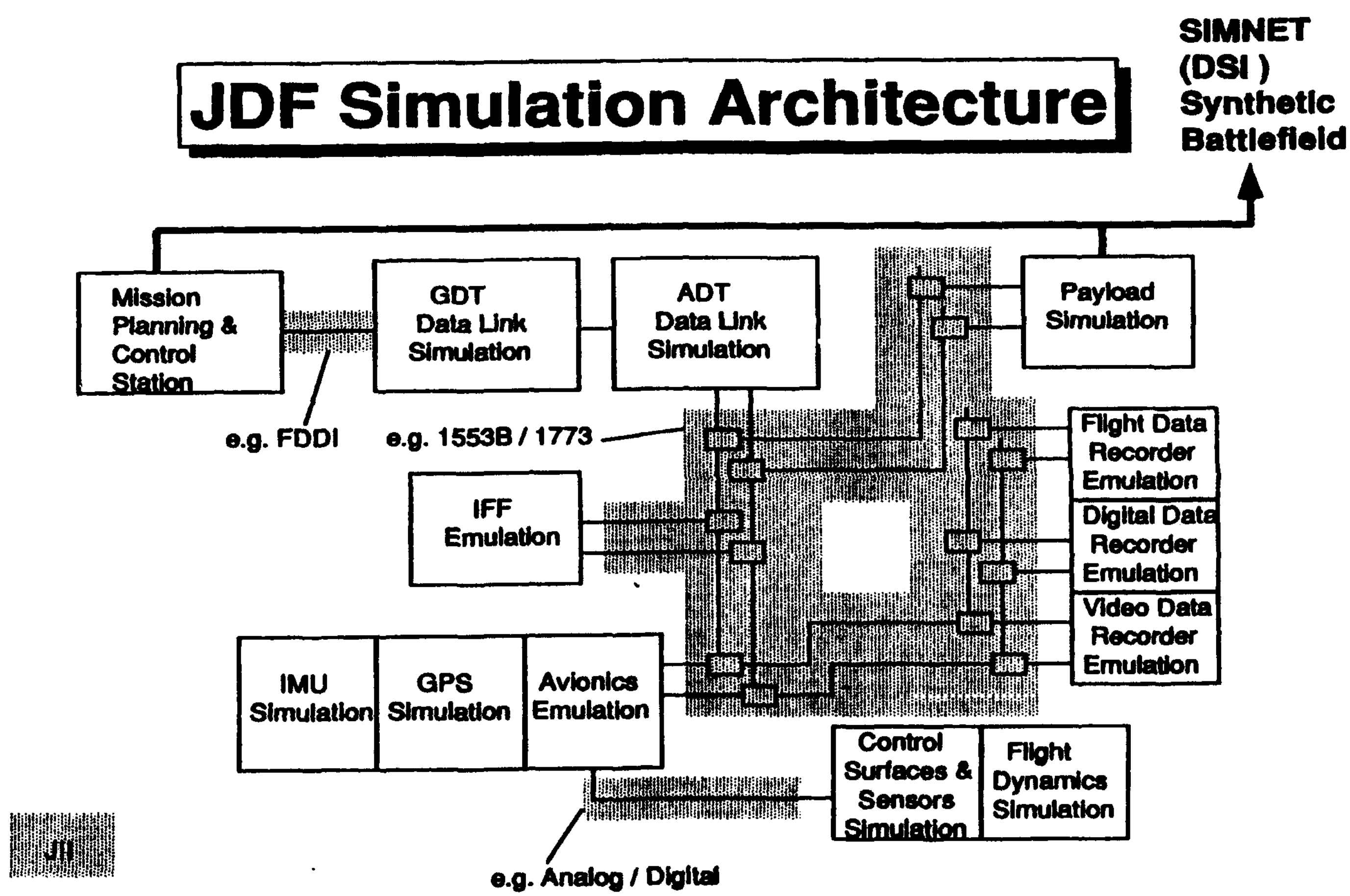

Figure 2. JDF Simulation Architecture

(Source: CRA 1992)

- Simulation of joint forces, joint warfare command and control, including some aspects of ground warfare
- Message generation to create scenario-driven data streams to stimulate and/or interact with C^2 support systems
- Simulation of proposed systems, forces structures, and C^3 (command, control, and communications) architectures

For SERCES, the RESA would simulate the ship board functions and the larger sea and enemy environmental activities needed for a VTOL-UAV mission.

2.4.3 Overall Interconnections

The interconnection among these facilities was achieved through the Defense Simulation Internet (DSI) via the IDA Simulation Center node. RESA could address "CONOPS" and the representations of the "real war." During MUAVEX-02 the UAV was to have been represented through connections with the JDF. It was planned that MUAVEX-03 and MUAVEX-04 would add more "real" hardware to that simulation network, including connections to the CIC of an actual ship.

2.5 RELATED ACTIVITIES

The simulation aspects of the ARPA/ASTO WAR BREAKER program seeks, via a distributed simulation network, to evaluate the effectiveness of different air-to-ground weapon and support systems in attacking critical mobile targets. The WAR BREAKER activities started shortly after the SERCES efforts began but were funded at higher levels and were driven by a higher priority. A major demonstration of WAR BREAKER was conducted at IDA during December 1992; that effort successfully interconnected over 20 simulations or simulators of aircraft and supporting systems. The Scud hunt mission during the last few days of the Persian Gulf war was used as the simulation scenario. The DSI supported the Phase 1 demonstration of WAR BREAKER. Three of the facilities participating in that particular WAR BREAKER demonstration were RESA, JDF, and IDA.

There were many other ongoing efforts related to the SERCES activities. These included the Defense Modeling and Simulation Initiative [DMSO 1993], the Science and Technology (S&T) Thrust 6, Synthetic Environments [SESP 1993], and many complimentary DARPA activities, including the Synthetic Theater of War (STOW) and the Interconnection of the Army Reserve and National Guard armories. These last two efforts were included as Advanced Technology Demonstrations within the S&T Thrust 6.

3. MUAVEX-01

The Maritime Unmanned Aerial Vehicle Exercise One (MUAVEX-01) was conducted entirely within the RESA laboratory. A layout of how RESA was used in this exercise is shown in Figure 3.

The purpose and objectives[4] of the MUAVEX-01 were accomplished by conducting an interactive simulation exercise in which the VTOL-UAV was employed in both realistic pre-war and wartime environments. This exercise provided a means to refine the concept of operations and to examine selected Measures of Performance (MOP) of the VTOL-UAV. A more detailed description of this exercise and its results is given in the *RESA Exercise Report* [NRaD 1992a].

3.1 SCENARIO DEVELOPMENT

One of the main objectives of the VTOL-UAV program office was to determine which missions were most appropriate for the vehicle. The VTOL-UAV requirements documents identified several potential missions including both the RSTA and Anti-Ship Missile Defense (ASMD). Two simulation exercises were established to gain insights into the advantages and disadvantages of employing the vehicle in these two missions. These focused on VTOL-UAV sensor and platform performance in the Persian Gulf region in both pre-war and wartime environments. Three scenarios were developed:

- MUAVEX-01A RSTA Operations
- MUAVEX-01B ASMD Operations Without UAVs
- MUAVEX-01C ASMD Operations With UAVs

A full description of these scenarios is included within the SERCEX-01 Scenario Overview [SSO 1992]. A brief summary of these scenarios is given in the following sections.

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[4] See Section 1.2.

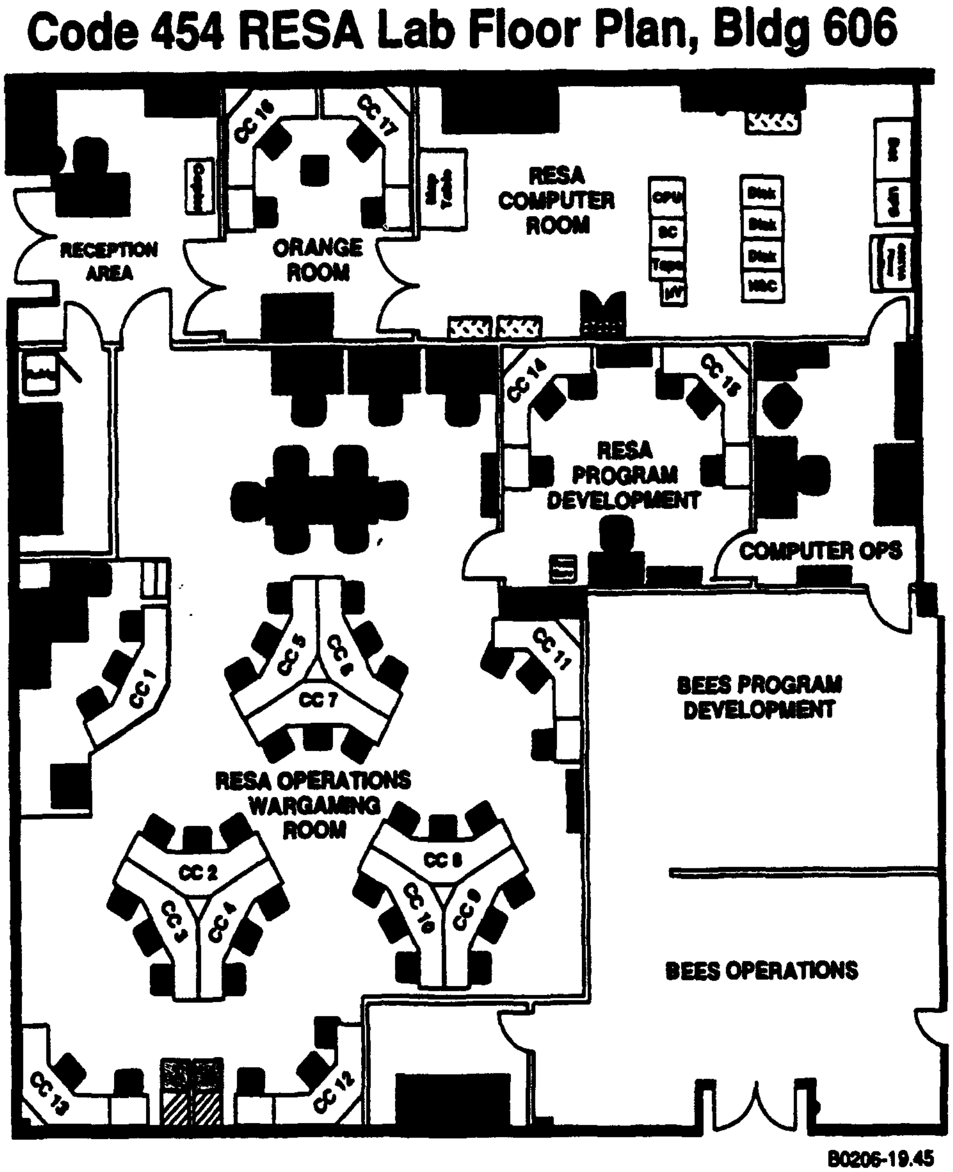

Figure 3. RESA Laboratory Configuration

3.1.1 MUAVEX-01A Scenario

For the RSTA mission, MUAVEX-01A was established to examine the VTOL-UAV speed, endurance, and payload requirements. In this exercise a single Arleigh Burke DDG-51 destroyer was tasked to perform independent barrier search operations to locate contraband-carrying ships. The destroyer had a complement of four VTOL-UAVs to carry out detection, classification, and identification functions during periods of both daylight and darkness. Three different sensor packages were tested simultaneously under consistent scenario conditions by using three different RESA views. The sensor packages were FLIR, SAR, and a combination of FLIR and Surface Search Radar (SSR). Specified sensor parameters and vehicle speed and endurance parameters were used in the exercise.

3.1.2 MUAVEX-01B and -01C Scenarios

For the ASMD mission, a war environment was assumed within the Persian Gulf and a Surface Action Group (SAG), consisting of one Aegis cruiser, one Spruance destroyer, and two Arleigh Burke destroyers, was tasked to escort 10 oil tankers out of the Gulf. MUAVEX-01B called for completion of this assignment without the use of UAVs, while MUAVEX-01C had four UAVs on each of the Arleigh Burke destroyers. Two of the UAVs were initially configured with FLIRs and the other two with ASMD jammers. The sensor packages could be changed, if needed, but with a 30-minute delay for replacement. Inherent within these scenarios were aspects which would also give data relative to a RSTA mission.

It was assumed that air superiority in the region was not yet fully established and only reduced air resources were available to the SAG. Enemy capabilities included five SAGs (but with limited targeting capabilities) located through out the Gulf, and numerous land-based and oil-rig-based surface-to-surface and surface-to-air missile (SSMs and SAMs) sites distributed along the coast of the Gulf.

3.2 SUBSYSTEM MODELING

All of the simulations in MUAVEX-01 were conducted in the RESA facility. Modifications were made to the existing RESA computer software and hardware to adequately represent the CIC of an Arleigh Burke destroyer, the LAMPS helicopters, and the relative ship locations including targets and commercial ships. The VTOL-UAV was represented by subroutines supplied by the UAV JPO and its contractors, including the speed, endurance, and basic maneuver capabilities of the UAV plus characteristics of the two radars and FLIR sensors. The VTOL-UAV and sensor representations were of a reduced fidelity so as to be easily integrated into the RESA environment. The FLIR imaging sensor did not use a

"man in the loop" to view the sensor data but instead used a probabilistic model to determine acquisition of ship targets.

3.3 EXERCISE PLANNING

The exercise called for many organizations and personnel to prepare equipment and data. Experienced officers from the fleet were requested to operate the CIC and conduct the VTOL-UAV mission planning and operations.

Once the scenario had been outlined and the general simulation capabilities of all the systems involved were defined, considerable efforts were needed to address the myriad of details necessary for a successful exercise. Numerous audits were conducted to ensure the basic software subsystem representations were reasonably correct and would interface with the other subsystem representations.

Four fleet officers volunteered to assume the roles of the key operational positions in the exercise. They were given basic training on the simulation equipment and the systems being examined.

3.4 THE EXERCISE

MUAVEX-01 was divided into three parts. Each is reviewed in the following sections.

3.4.1 MUAVEX-01A

Seven combinations of VTOL-UAV speed (four options) and endurance (three options) were evaluated twice in a six game-hour scenario. The runs were conducted from 1500 to 2100 local Gulf time to evaluate sensor performance during daylight, dusk, and at night. Players were permitted to have two VTOL-UAVs airborne at the same time; however, only one VTOL could data-link track information back to the destroyer at a time.

To make the situation more realistic a constant flow of merchant shipping was present with between 8 and 12 neutral ships crossing the barrier each hour. In addition a fleet of fishing vessels were simulated and they maneuvered very irregularly in the area.

Each run consisted of (1) a UAV launch, (2) the UAV flying a bow-tie pattern to detect shipping, (3) a direct flight to suspect ships to classify and/or identify the ship as one carrying contra-band or one which was not carrying contra-band, and (4) the UAV returning to the host ship.

3.4.2 MUAVEX-01B and -01C

Prior to both exercises, the SAG commander organized his ships and used the LAMPS helicopters and VTOL-UAVs (in -01C) to precede the SAG and identify surface contacts. In -01C the commander ordered two UAVs to be configured in the ASMD role and positioned them to protect the SAG from the two most likely threat axes. Initial engagements in both scenarios were Blue (U.S. forces) attacks on Orange (enemy) SAGs. Orange countered by firing anti-surface missile "down the line-of-bearing" of the incoming Blue missile and later used the same tactic when Blue activated air search radars.

3.5 POST-EXERCISE ANALYSES

Considerable data was collected during this exercise, much of it used to gain better insights as to the needed performance characteristics of the UAV and the sensors. Also of value was the nature of how the fleet operators used the UAV and their opinion as to its effectiveness in the scenarios. Insights were gained in the preparation of the follow-on exercises.

3.5.1 MUAVEX-01A Results

It was discovered during the exercise that the fidelity of the FLIR and SAR sensors was not sufficient to demonstrate realistic operator use. The test results bore this out in that the operators were able to classify and identify more than one ship target at a time using just the wide field-of-view of the FLIR. There was no need to use the FLIR mid and narrow fields-of-view. The modeled SAR system had such a short detection range and long (about one minute) identification time that the operators were forced to slow down the UAV and/or make numerous passes through a small area. There was some "leakage" of ships across the barrier when only the SAR was used. Refinements in the representation of the FLIR were planned for MUAVEX-02 and it was decided to eliminate the SAR as a sensor for further experimentation within SERCES.

3.5.2 MUAVEX-01B and -01C Results

During the MUAVEX-01C tests, e.g., where the VTOL-UAVs were also configured with FLIRs to conduct reconnaissance, the SAG commanders were able to quickly gain a better understanding of the surface situation than during the MUAVEX-01B tests. The UAVs were better able to fly close to and classify ships in areas too risky for the manned LAMPS helicopters to fly. This result was expected: by having more airborne assets able to

classify and identify targets, the commanders would inherently have a better understanding of the situation.

The outstanding effectiveness of the modeled ASMD jammers on the VTOL-UAV was rapidly recognized by the fleet participants. Concerned less with being hit by enemy missiles from an unidentified track, the SAG commanders tended to be more selective in their choice of targets and reduced the number of missiles fired during the earlier portion of the mission. The relatively poor targeting capability of the enemy SSMs caused them to focus most of their missiles on attacking the large radar cross section tankers rather than warships. As the mission progressed and the number of UAV assets were reduced by losses to enemy fire and/or maintenance problems, the SAG commanders re-assigned the role of the UAVs from performing RSTA to that of ASMD.

In both exercises, the target-rich enemy environment caused the Blue forces to expend all of its SSMs before entering the Strait of Hormuz. Once all of the Blue force SSMs were expended, Orange began to take a heavy toll of Blue ships within MUAVEX-01B. But in -01C, the ASMD UAVs continued to defend the SAG through the Strait and the losses were considerably less. Both exercises were stopped when both Orange and Blue had expended all available weapons.

Within these exercises the UAV reconnaissance version contained only a FLIR. To achieve effective operation, the FLIR operator needed an external cue to know where to fly the UAV and to point the FLIR. This cue generally came from the LAMPS helicopter or from the ship's SSR. The fleet personnel supporting the exercise suggested that an SSR (similar to the sensor package used in MUAVEX-01A where a FLIR and SSR combination was used in the barrier search mission) and/or an ESM pod be added to the UAV sensor suite.

The speed and endurance seemed satisfactory in that the fleet personnel used most systems to their given operational limits.

3.5.3 General Observations

The following are observations made by the fleet personnel and the analysts regarding the design aspects of the UAV and its ability to support the barrier and SAG operations. (See [UAV JPO 1992]).

- The UAVs permitted significant improvement in the overall ability and effectiveness of those ships to carry out their assigned missions.

- The senors limitations were more of a constraint in the overall effectiveness than was the various vehicle speed and endurance parameters.
- The support from UAVs in an ASMD role was so significant that UAVs operating in that role were favored over UAVs operating in a reconnaissance role. This could have been due to the inadequate representation of the FLIR.
- UAVs with a stand-alone capability would be more effective in reconnaissance missions if an SSR or ESM package was added.

In addition to system design observations, the following observations were made regarding the SERCES process.

- This first exercise was a good means to model the entire system operation before beginning the networking with several sites. It helped attain a good overall perspective of the detailed engineering aspects of a proposed system and its operation in near "real world" operations.
- The exercise permitted early identification of areas and parameters needing more attention by systems engineers, the detailing of recommended scenarios, and the establishment of effectiveness and performance measures. The accomplishment of MUAVEX-01 required extensive effort and many assumptions were made which were not completely verified.
- Incorporating fleet personnel was most beneficial because they added a "real world" dimension to the analysis that may have been lost if "just" the usual R&D personnel were involved in the exercise.
- The sensor package modeling needs to be done at a greater level of detail and with validated models so that more realistic physical processes and system engineering issues can be resolved during follow-on exercises. Other sensors packages should also be considered, e.g., SSR and ESM for the RSTA missions.

4. PLANNING FOR SERCESEX-02 (MUAVEX-02)

The plan for MUAVEX-02, renamed SERCESEX-02 in early 1993, was to use the RESA facility to simulate a majority of the warfare environments and the JDF to supply an engineering level simulation of the VTOL-UAV. The JDF simulations were to interact with the RESA simulation, with the result that many detailed systems engineering issues would be examined. This was a major step from MUAVEX-01 where models of the UAV were incorporated within RESA.

SERCESEX-02 initially had three main goals:

- To initiate and test development of a methodology for conducting SERCES studies in support of the systems engineering process.
- To verify and/or expand the results from MUAVEX-01, and to further examine force-level considerations in the employment of the VTOL-UAV.
- To evaluate the effectiveness of the network interconnections among the three facilities, i.e., IDA, RESA, and JDF.

4.1 INTERCONNECTIONS WITH THE JDF, RESA, AND THE IDA SIMULATION CENTER

As part of the WAR BREAKER Phase 1 activities demonstrated in December 1992, the JDF, RESA, and the IDA Simulation Center were interconnected using the DIS 1.0 protocol. That interconnection permitted the exchange of protocol-data-units (PDUs) which are used to interconnect simulators via the DSI. Proper data formats were established and images and data were exchanged among the three facilities. Figure 4 shows one of the proposed SERCESEX-02 functional configuration.

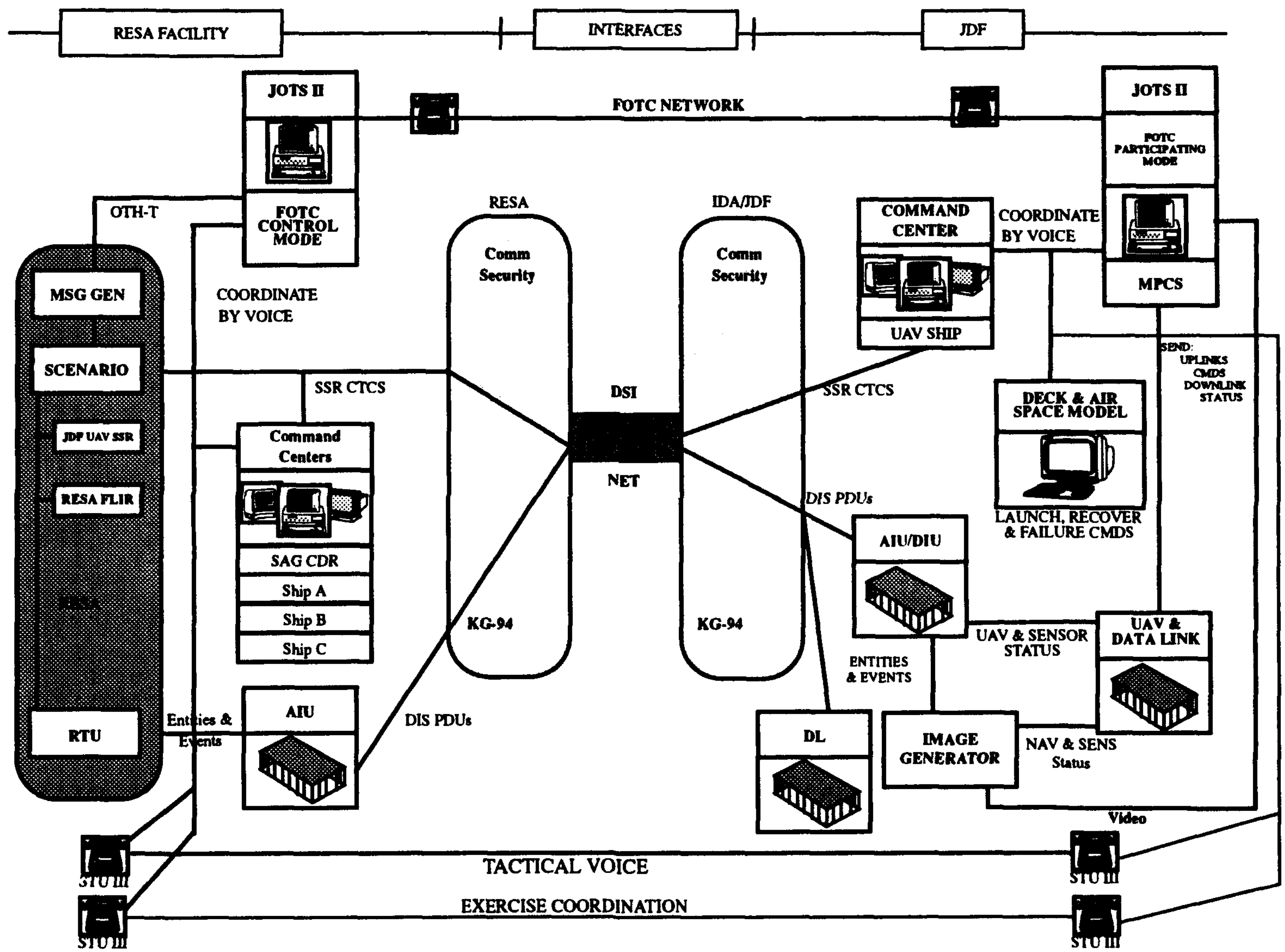

Figure 4. SERCESEX-02 Functional Configuration
(Source: DACOR 1993a)

The simulation capabilities to be used in this exercise from the RESA, JDF and IDA Simulation Center are included within Tables 1, 2, and 3, respectively.

Table 1. RESA Simulation Representations[a]

Platform Performance	**Operational Environment**	**Payload (Medium Fidelity)**
Identification	Weather	Sensors
Position	Acoustic	Decoy
Movement	Electromagnetic	Decoy
Status		
Data Link Performance	**Data Distribution**	**Command and Control**
Connectivity	Force Level	Force Level
		Unit Level
Mission Planning and Control	**Simulation Translation/ Protocol Functions**	
Surrogate	RESA Translator Unit (RTU)	

a. SERCESEX-02 Exercise Evaluation Plan, October 8, 1992 [SEEP 1992].

Table 2. JDF Simulation Representations[a]

A/V Motion and Maneuver	**Visualization A/V**	**Sensor Imagery Display**
Flight Dynamics	Terrain/Wakes	FLIR
Launch Recovery	Platform/Vehicle	TV
Mission Planning	**A/V Control**	**Payload Control/ Performance**
Route Planning/Validation	Single Unit	Image Sensor
Payload Planning/Validation	Multiple Units	Detection/Processing
Datalink Processing		

Table 2. JDF Simulation Representations[a] (Continued)

Simulation Translation/ Protocol Functions	Data Link Control
AIU as the SIMNET/DIS Interface	Command & Status
	Sensor Downlink

a. SERCESEX-02 Exercise Evaluation Plan, October 8, 1992 [SEEP 1992].

Table 3. IDA Simulation Representations [a]

Simulation Translation/ Protocol Functions	Exercise Support Functions	Network Conectivity
DIS-SIMNET Protocol Translator	Data Logging	IDA/JDF Gateway
	Stealth Management	
	Semi-Automated Forces	

a. SERCESEX-02 Exercise Evaluation Plan, October 8, 1992 [SEEP 1992]

4.2 SUBSYSTEM MODEL REFINEMENT

The UAV system simulation developed for MUAVEX-02, as opposed to software running with RESA, was a stand-alone UAV system simulation configured for real-time operation with a system operator. The interface with the operator was developed to look and feel to the operator just like an actual UAV MPCS. The MPCS contained windows for control and status monitoring of the UAV and payloads, generation of operator reports, a two-dimensional map for display of track information received from RESA, and a window for displaying the image sensors view of the synthetic environment. Eleven different ship target models within the synthetic environment were viewed, placed and controlled by RESA using PDUs. The synthetic targets and environment were modeled to appear like FLIR imagery to the UAV system operator. Other subsystems included hardware to support from one to four UAV system models and select between those models, a deck and air space model to simulate launch and recovery issues and to maintain a reliability model, an image generator to create the imaging sensor view of the environment, an Advanced Interface Unit (AIU) and Digital Interface Unit (DIU) to interface between the DIS network and the UAV system simulation, a data logger to store and playback all PDU traffic over the network, and a RESA Remote Command Center (RRCC) to simulate the console in the UAV host ship CIC. Communications equipment was provided to improve realism between the UAV operator and the ship tactical action officer tasking the UAV in the exercise.

The FLIR model used by RESA in MUAVEX-01 was completely re-analyzed at a higher fidelity and the capabilities were verified in a review with key infra-red researchers with the Naval Research Laboratory. The effects of weather and distance were also refined and verified with those individuals. The final system, modeled after an existing FLIR product, contained three selectable fields of view and a scan capability. The results of the FLIR analysis were used to adjust the appearance of the simulated FLIR graphics so that ship targets of various size were detectable, recognizable, and identifiable at the appropriate ranges.

The SSR model was refined for exercise 02 to properly represent the capabilities of a system that could be incorporated onto a UAV. The ASMD model was to be the same as used in the first exercise. The SAR payload was eliminated for MUAVEX-02.

4.3 SCENARIO REFINEMENT

The scenarios used in MUAVEX-01 were also be used here, i.e., the barrier patrol and the SAG escort of tankers from the Persian Gulf. Minor refinements in the operations were identified (SERCESEX-02 Scenario Overview and Analysis Plan [SSOAP 1992]).

4.4 PROCESS MODEL DEVELOPMENT

With difficulties in coordination and inter-relationship of activities among the various SERCES organizations both before and during MUAVEX-01, the decision was made to develop a model of the exercise development process. This executable SERCES Program Process Model (PPM) helped to reduce the coordination problems and to resolve many of the dilemmas during the initial MUAVEX-02 planning and engineering activities. Details of the PPM can be found in Section 5.

4.5 TERMINATION OF PLANNING ACTIVITIES

In January 1993 the MUAV effort was changed from an acquisition program to a technical demonstration program. This move by the UAV JPO lead to the decision by ARPA in March 1993 to complete the SERCES program during FY 1993 since the MUAV was no longer a suitable test case for SERCES. Planning continued in earnest for MUAVEX-02 until May 1993 when it was decided by ARPA to move the UAV system simulation to the new WAR BREAKER facility and merge the effort with the WAR BREAKER program. The UAV system simulation, which had been tested with RESA over the DSI network using DIS 1.0 PDUs, was reassembled at WAR BREAKER and upgraded to operate with DIS 2.03 PDUs. The program process model development was continued to a success-

ful conclusion, demonstrated, and documented. The final UAV system simulation configuration was documented by Cambridge Research Associates; see [CRA 1993a] and [CRA 1993b].

5. PROGRAM PROCESS MODELING ACTIVITIES

During the planning for MUASVEX-02, participants in the SERCES activity realized the difficulty in getting good coordination among all the various organizations and how significant efforts were needed to properly plan and execute such an exercise. This difficulty easily occurs in a program using distributed management and involving organizations at opposite ends of the country. A similar coordination problem was also noted within the WAR BREAKER Phase 1 demonstration activities. The original SERCES objective was to devise a procedure for effectively applying modeling and simulation techniques to acquisition programs in a manner so as to reduce the acquisition time. The combination of this objective and the coordination problems led to the decision to develop a model of the SERCES exercise development process. This section addresses the process that was followed in selecting useful tools and methodologies, the training in the use of the FORESIGHT[5] modeling tool, the program process model which was developed to model MUAVEX-02 and be used to direct future exercises, and the outcome from using the tool.

5.1 MODELING TOOL SELECTION

Several organizations[6] were involved (each at different levels of support and involvement) in MUAVEX-01, but the ratio of their involvement was to change significantly and, in general, increase for SERCESEX-02. There was also much difficulty in the intercoordination among all those parties as the details for MUAVEX-01 were being defined and implemented. During a major program review in January 1993, these difficulties were openly discussed and options were sought to help reduce the coordination problems and resolve the dilemmas. The VTOL-UAV program office had used the FORESIGHT modeling tool as part of its system modeling effort. Because of the success with that effort, it was recommended that FORESIGHT be the basis for development of a program process model.

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[5] FORESIGHT was developed, and is a trademark of, NU Thena Systems, Inc.

[6] UAV JPO, PMA-263, ARPA, SAIC, IDA, NRaD, DACOR, Cambridge Research Associates, ETA, SONALYST, PARAMAX, and selected field operation groups.

The FORESIGHT tool is a software planning program which is part of the "family" of the functional flow block diagram concepts. Its modeling constructs are based on an extension of the Extended System Modeling Language (ESML) developed by system designers at Boeing, Honeywell, and Hughes [Bruyn 1988]. The VTOL-UAV program office was one of the first major users of the tool, using it to perform the following tasks:

- Analysts could put many different activities into proper interrelationships.
- The engineering office could now ensure that the needed human and physical resources were available at the correct time and place to give support to the preparation of the documents.
- Inconsistencies were identified in the flow of people, material, and funds.
- The accomplishment of and interrelationship among tasks could be monitored once they began.

During the review it was acknowledged that IDEF[7] was a tool which the Department of Defense had encouraged most offices to use in similar situations. IDEF has been around for many years and has been extended to comprise many additional features including information, data, system dynamics, human-system interaction, architecture, and artifact modeling [Rupp 1993]. However, unlike Foresight's modeling language, IDEF is not executable.

After reviewing the options, ARPA and the UAV JPO decided that since the VTOL-UAV program office, Cambridge Research Associates, and DACOR[8] were familiar with FORESIGHT, it would be the best tool to use as a basis in planning for the next exercise. Additionally, if the results from this application were very helpful, it was to be considered for use within the WAR BREAKER Phase 2 simulation.

The program process model, developed from FORESIGHT, was expected to assist in the following activities:

- Showing the critical inter-relationships between tasks
- Identifying missing processes and positions

[7] The acronym IDEF originally stood for the ICAM Definition language. ICAM (Integrated-Computer Aided Manufacturing) was the sponsoring organization within the U.S. Air Force for the original IDEF development efforts. More recently, the Information Integration for Concurrent Engineering (IICE) Program has assumed responsibility for the continued development of the advanced methods of IDEF. The IICE Program now refers to IDEF as the Integrated Definition Language [Rupp 1993, p. 328].

[8] Cambridge Research Associates and DACOR were contractors supporting the VTOL-UAV program.

- Defining responsibility by the lowest level of tasking
- Helping to optimize use of resources and scheduled time
- Conducting "what-if" analyses

5.2 WHAT IS FORESIGHT

FORESIGHT supports the systems engineering process with four broad capabilities that are integrated through an executable system model [DACOR 1993b]:

- The development of complete, correct, and unambiguous specifications
- The design and evaluation of critical system capabilities with operational prototypes
- A design verification framework
- An integration and test framework

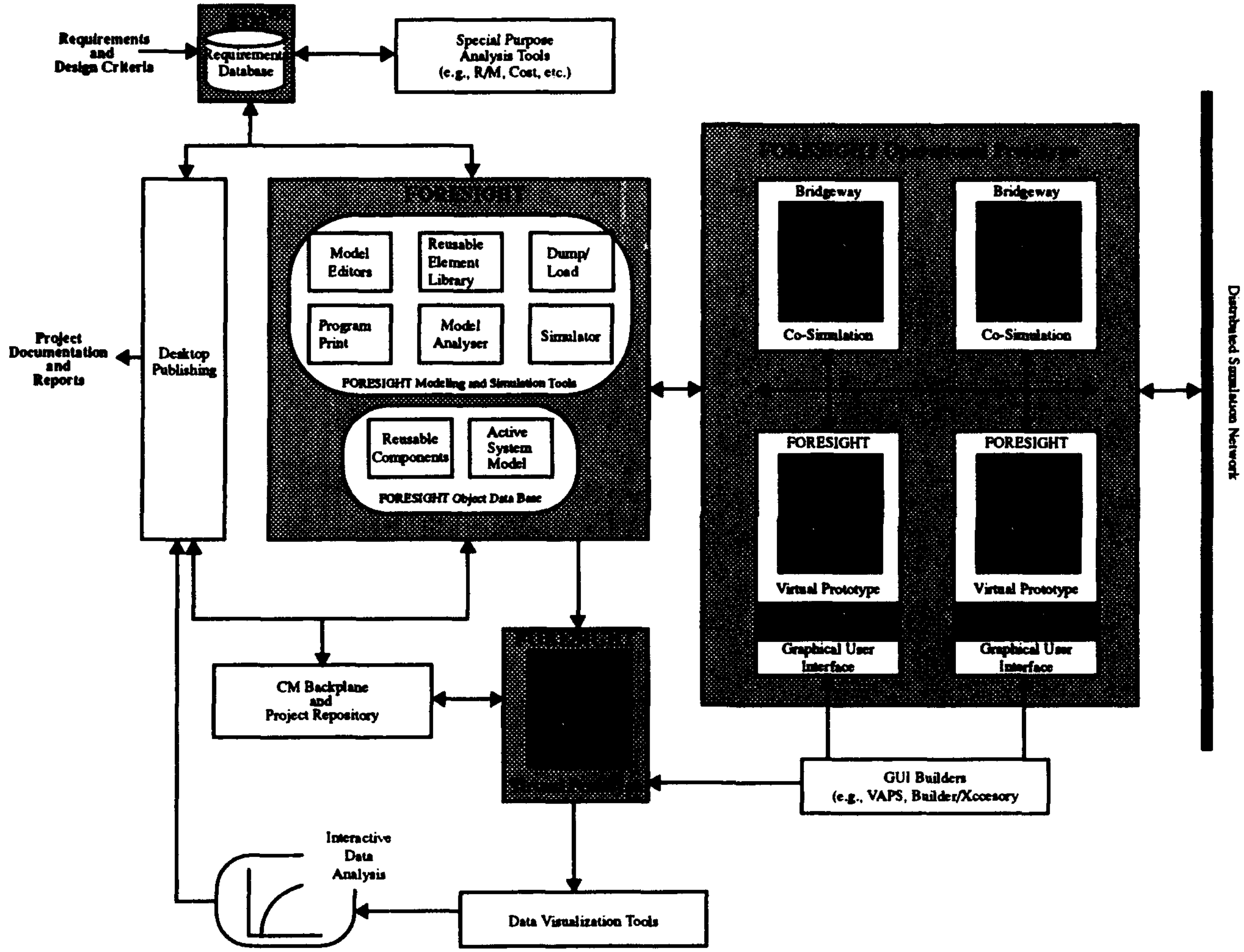
The model language and execution environment supports full functional, behavioral, performance, and information modeling and analysis. It also has enhances timing and data flow capabilities.

FORESIGHT supports the complete definition of executable process models, the dynamic analysis of organizational and system processes, and "what-if" analysis of organizational and system processes. It offers support in the "full life-cycle" of system engineering efforts (Figure 5).

5.3 TRAINING NEW PEOPLE IN ITS USE

To incorporate this new tool within the SERCESEX-02 planning efforts, a training session was established where key representatives were brought together to learn the basics of the program and to begin its application for the SERCESEX-02. Training manuals provided the necessary guidance on its use, and equipment was purchased to allow for interactive use of the model within three major facilities—NRaD, the JPO, and Cambridge.

One of the key outcomes of the training was an even greater appreciation of the number of details to be understood and/or decided upon to adequately represent the many different facets of both the actual simulation of the VTOL-UAV mission planning, operations, and support, as well as the activities to be accomplished to conduct the actual simulation exercise. These details surfaced as the many different levels of functional flow block diagrams within FORESIGHT were being constructed and interconnected.



- Requirements Verification
- Complete and Correct Specification Development
- Process Analysis/ Evaluation
- Evaluation of Critical Capabilities and Alternatives
- Design Verification Framework

Figure 5. FORESIGHT System Engineering Environment
(Source: DACOR 1993)

The initial training was accomplished in a matter of a week, but considerably more was learned as the individuals began to use the program in planning for the SERCESEX-02.

5.4 PROGRAM PROCESS MODELING ACCOMPLISHMENTS

During the January-June 1993 period, over 180 functional block diagrams were defined and interconnections identified and understood. The effort progressed from initial static relationships among the blocks to an executable "dynamic" status where the information and activity flowed as a function of time and these were represented within the model. Since FORESIGHT addresses functional items and the flow between them, the effort included interconnecting FORESIGHT with a project scheduling tool, MicroSoft Project. That combination added the capability to display the results of the dynamic analysis in traditional project management forms: PERT, GANTT, resource sheets, etc.

A July 2, 1993, demonstration of the executable program graphically demonstrated the flow of activities needed to take place before SERCESEX-02 could occur. The needed manpower and equipment were studied and compared in a time-dependent manner with the available resources. The analyses of the results helped the management to understand where bottlenecks were likely to occur and where people were overcommitted. In the July 2nd demonstration, many variables were introduced which showed the flexibility of the system to address "what-if" questions.

5.5 LESSONS LEARNED IN THE INITIAL APPLICATION OF THE PROCESS MODEL

Many different "lessons learned" were observed during this phase of applying FORESIGHT to the SERCESEX-02 planning process. A full description of them is contained in DACOR [1993] and summarized below.

- A solid knowledge of the system, scenarios, environment, development processes and the modeling process is needed by nearly all of the participants in the exercise. People who are "experts" on the process being developed are needed to establish a full understanding of the individual steps and sequence of activities. The decomposition of the functions of both the system and the simulation process was found to be very complicated, and people who were very knowledgable in those areas were needed to actively participate in the effort. The effort also required people be available who were "experts" in the use of the FORESIGHT tool; they helped speed the rapid implementation of the process.

- Approximately 60% of the time was spent in understanding and breaking down the processes to be modeled. It was a valuable learning experience about how the envisioned process and system were to work together.
- Although unilateral decisions by a model leader may have been more efficient, all personnel within the exercise needed to be closely involved in most all activities and be part of each phase of the decision processes. Since many activities affected a large number of people, everyone needed to have an input into the decision process.
- It was initially thought that a facilitator might be needed to actively and aggressively help arbitrate the many conflicts. However, most of the conflicts were minor and were resolved before they got "out-of-hand." Having someone who was responsible to resolve major conflicts would still have been useful though.

6. CONCLUSIONS

With the change in the JPO's VTOL-UAV activities from a developmental program to a technology demonstration project, the goals and plans for the SERCES program were significantly reduced. Accordingly, the primary goal of SERCES, offering the MUAV-JPO significant insight to the performance, mission, operational procedures, and ship interface, was not accomplished. From MUAVEX-01, the following conclusions were drawn:

- The MUAV (as modeled) appeared to enhance the mission effectiveness of the Surface Action Group.
- The barrier patrol scenario simulation operated well but the FLIR and SAR subsystems were not adequately modeled. Because of this, no significant difference was found as UAV speed, endurance, and payload were varied.
- For the RSTA mission, errors in the FLIR capabilities permitted the UAV operators to just loiter and not dash to the targets. The UAV utilizations were complementary with the LAMPS operations.
- In the simulated ASMD mission, the operators always dedicated some UAVs to ship protection and in some cases pre-empted the use of UAVs from RSTA.

These results were very satisfactory. Elimination of the SAR model and a re-analysis of the FLIR model were planned for MUAVEX-02.

Much was accomplished from the planning efforts for SERCES-02 (formerly MUAVEX-02), which were completed prior to the early termination/redirection of the SERCES program. The following were the key highlights of those accomplishments:

- FLIR models were developed with the help of the Naval Research Laboratory personnel and the models were more representative of the performance of real systems.
- Network interconnections between RESA and the JPO's JDF were made and *pseudo* VTOL-UAV missions were flown to check-out various subsystems and operations.

- Improved scenarios and corresponding measures of performance were established to evaluate the system performance in the three activities.
- An expanded process modeling system was developed to facilitate the definition and execution of the many diverse activities needed to conduct this exercise.
- The completed UAV system simulation was included within the planned WAR BREAKER Phase 2 program.

Following the reduction in the scope of the SERCES program, the process modeling effort continued. By July 1993 demonstrations of the model's capability were given, showing the following:

- The executable program graphically demonstrated the flow of activities needed to take place before the formal SERCESEX-02 could occur.
- The required level of manpower and equipment was studied and compared in a time-dependent manner with the available resources.
- The analyses of the results helped management understand that bottlenecks were likely to occur and where people were overcommitted,
- The effort also included interconnecting the FORESIGHT with MicroSoft Project, a project scheduling tool. During the demonstration many variables were introduced to show the flexibility of the system to address "what-if" questions.

The program process model effort has been included within some aspects of the planning portions of the WAR BREAKER program.

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LIST OF ACRONYMS

ADT	Airborne Data Terminal
AIU	Advanced Interface Unit
ASMD	Anti-Ship Missile Defense
ASTO	Advanced Systems Technology Office (ARPA)
ARPA	Advanced Research Projects Agency
A/V	Audio/Visual
BFIT	Battlefield In-port Training
C^2	Command and Control
C^3	Command, Control, and Communications
CALS	Computer Aided Logistics System
CDR	Commander
CE	Concurrent Engineering
CIC	Combat Information Center
CMDS	Commands
CONOPS	Concept of Operations
CTCS	Contacts
DARPA	Defense Advanced Research Projects Agency
DASL	Distributed Assessment and Synthesis Laboratory
DIS	Distributed Interactive Simulation
DIU	Digital Interface Unit
DL	Data Logger
DMSO	Defense Modeling and Simulation Office
DoD	Department of Defense
DSI	Defense Simulation Internet

ESM	Electronic Support Measures
ESML	Extended System Modeling Language
FLIR	Forward Looking Infra-Red
FOTC	Force Over-the-Hill (OTH) Track Coordinator
GDT	Ground Data Terminal
GPS	Global Positioning Satellite
IDA	Institute for Defense Analyses
IDEF	Integrated Definition Language (formerly Integrated Computer-Aided Manufacturing (ICAM) Definition language)
IEEE	Institute for Electrical and Electronic Engineers, Inc.
IFF	Interrogation Friend or Foe
IICE	Information Integration for Concurrent Engineering
IMU	Inertial Measuring Unit
IR	Infra-Red
JII	Joint Intergration Interface
JDF	Joint Development Facility
JOTS	Joint Operational Tactical Systems
JPO	Joint Program Office
LAMPS	Light Airborne Multi-Purpose Station
MOA	Memorandum of Agreement
MOP	Measures of Performance
MPCS	Mission Planning and Control System
MSG GEN	Message Generator
MUAV	Maritime Unmanned Aerial Vehicle
MUAVEX	Maritime Unmanned Aerial Vehicle Exercise
NAV	Navigation
NRaD	Navy Research, Development, Test and Evaluation Division
OT&E	Operational Test and Evaluation
OTH-T	Over-the-Horizon Targeting

PDU	Protocol Data Unit
PMO	Program Management Office
PPM	Program Process Model
RESA	Research, Evaluation and Systems Analysis
RSTA	Reconnaissance, Surveillance, and Target Acquisition
RTU	Research, Evaluation and Systems Analysis (RESA) Translator Unit
S&T	Science and Technology
SAG	Surface Action Group
SAM	Surface-to-Air Missile
SAR	Synthetic Aperture Radar
SENS	Sensor
SIMNET	Simulator Network
SERCES	Synthetic Environments for Requirements and Concept Evaluation and Synthesis
SERCESEX	Synthetic Environments for Requirements and Concept Evaluation and Synthesis (SERCES) Exercise
SSM	Surface-to-Surface Missile
SSR	Surface Search Radar
STOW	Synthetic Theater of War
STU	Secure Translator Unit
UAV	Unmanned Aerial Vehicle
VTOL	Vertical Take-off and Landing